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Hoffman

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(54) **SENSOR MODULE WITH INTEGRATED DISCRETE COMPONENTS MOUNTED ON A WINDOW**

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(58) **Field of Search** 250/208.1, 216, 250/239; 348/373; 438/66, 116, 118; 257/433, 434, 432, 680, 629

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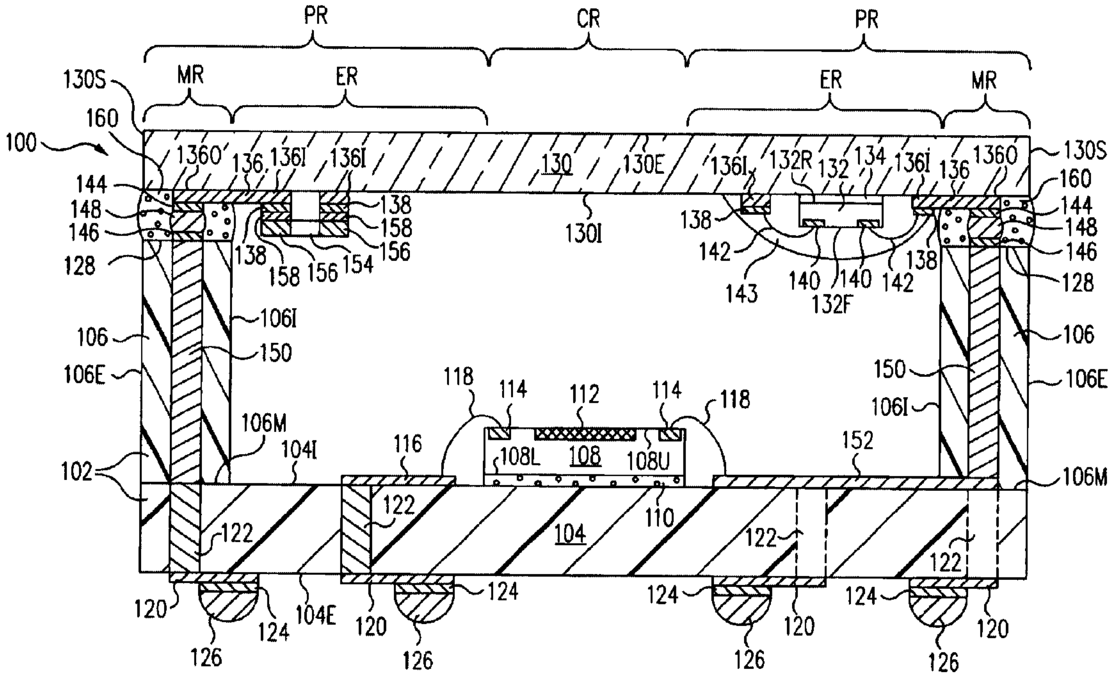
(57) **ABSTRACT**

An optical module includes a window having an interior, e.g., first, surface. The interior surface includes a central region and a peripheral region. A first electronic component is coupled to the peripheral region. The optical module further includes a substrate and an image sensor coupled to the substrate. The window is coupled to the substrate such that the image sensor is aligned with the central region of the window.

20 Claims, 5 Drawing Sheets



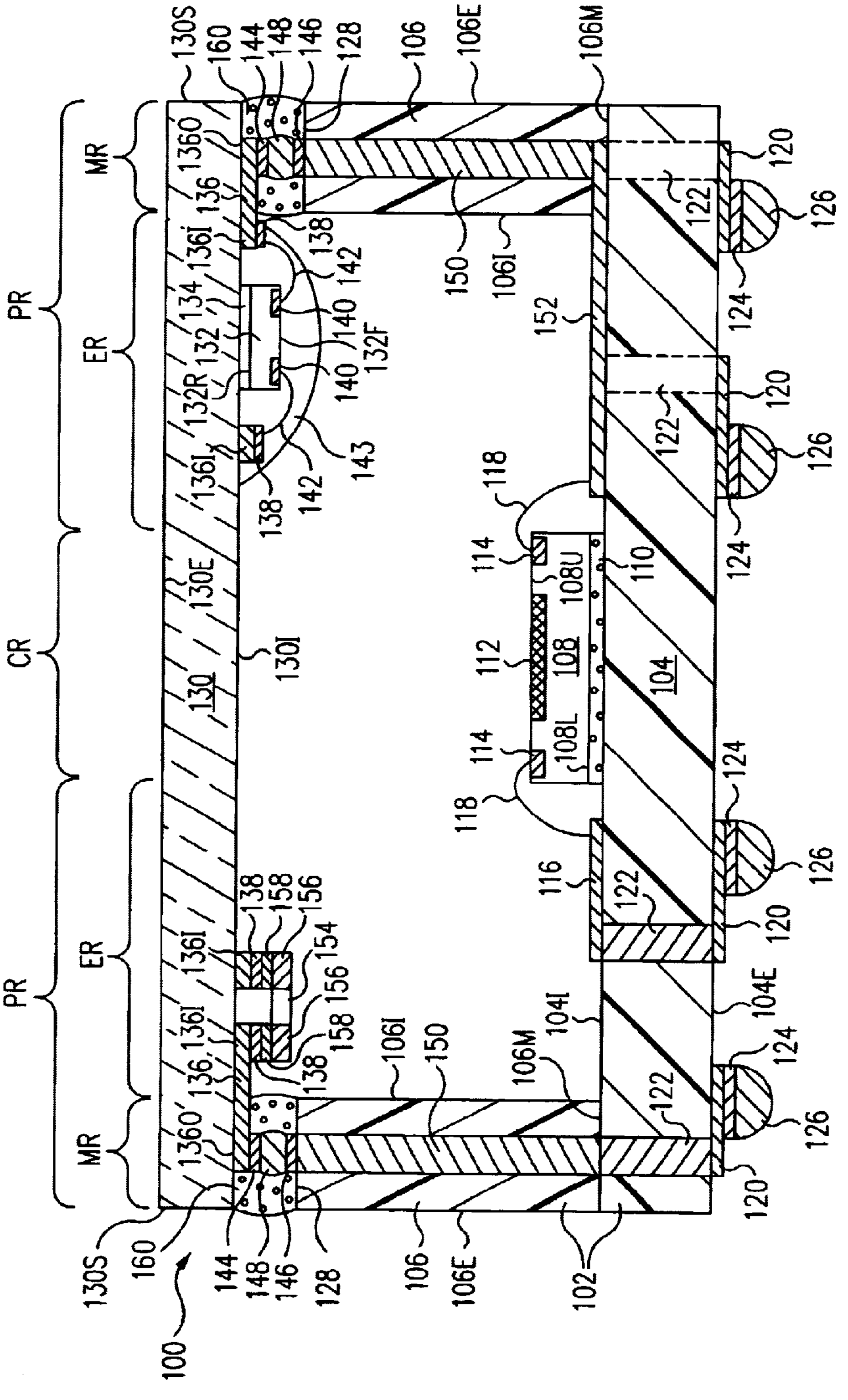

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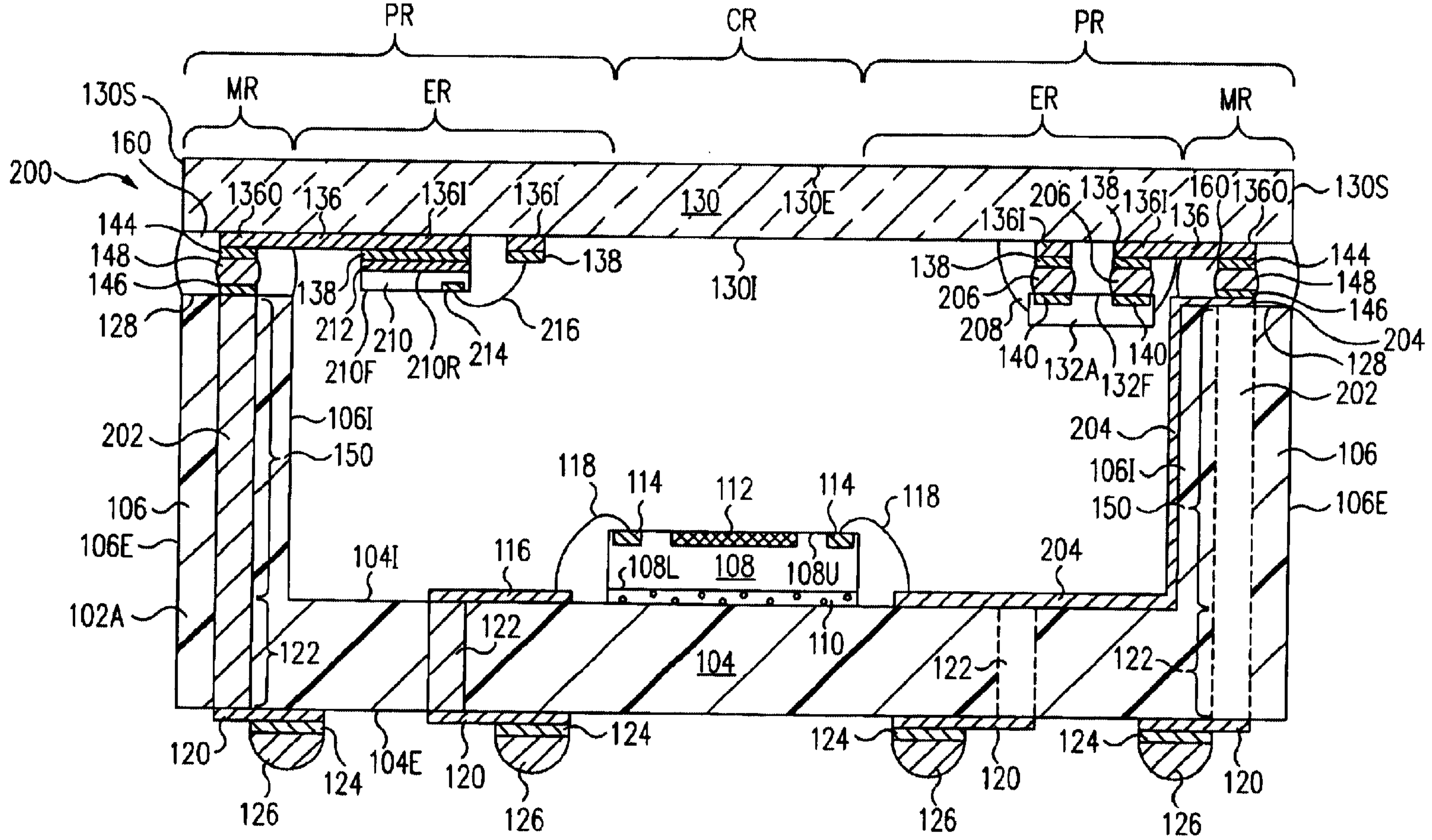
FIG. 1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104I
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FIG. 2

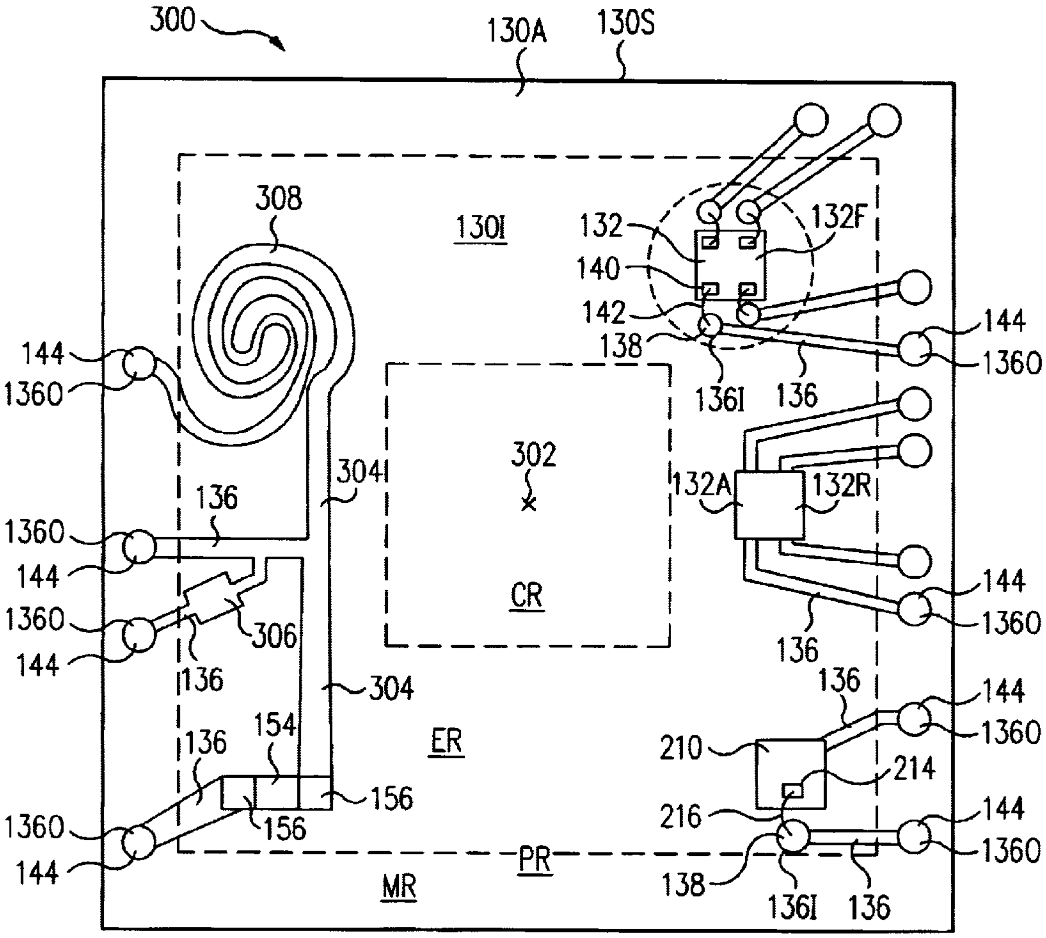
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FIG. 3

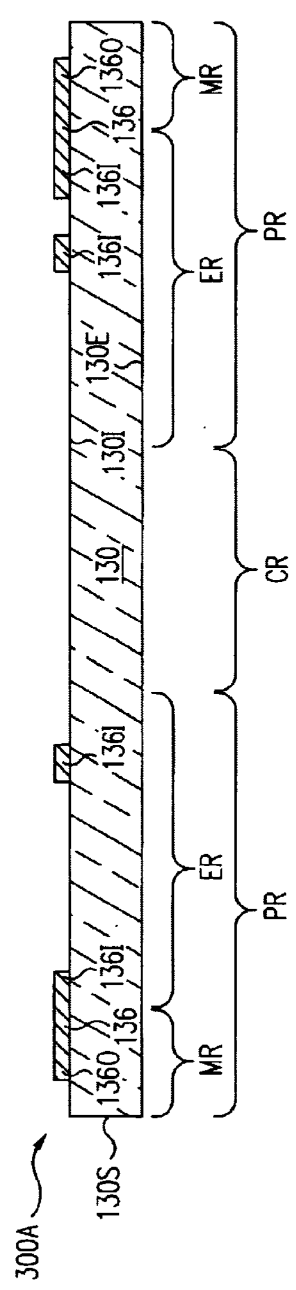


FIG. 4

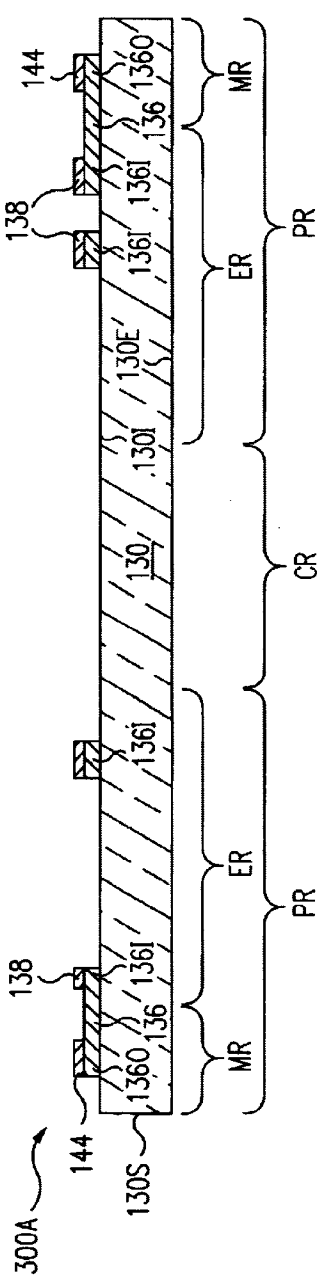


FIG. 5

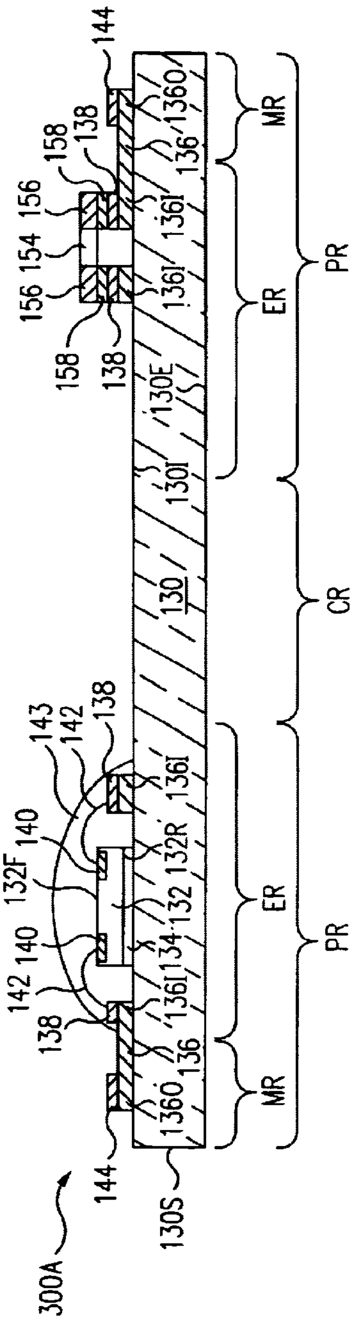
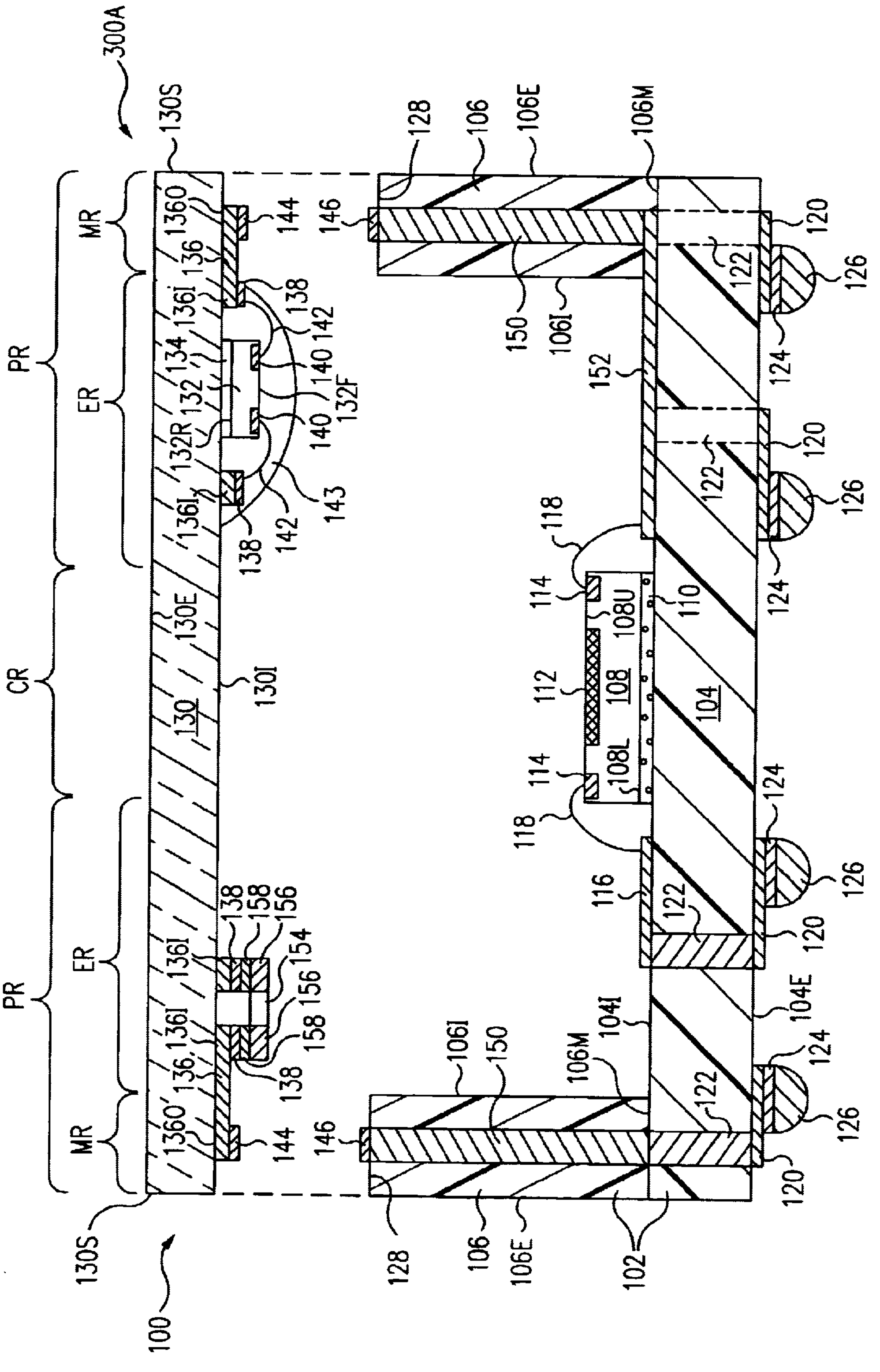


FIG. 6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106M
150
106I
152
118
114
108U
112
108
108L
110
104
116
122
120
124
126
104I
104E
158
156
154
102
100

FIG. 7

SENSOR MODULE WITH INTEGRATED DISCRETE COMPONENTS MOUNTED ON A WINDOW

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to the packaging of electronic components. More particularly, the present invention relates to an electronic component package and method of fabricating the same.

2. Description of the Related Art

Image sensors are well known to those of skill in the art. An image sensor included an active area, which was responsive to electromagnetic radiation. The image sensor was incorporated into an image sensor package, which protected the image sensor from dust and moisture.

To allow the image sensor to operate, other electronic components associated with the image sensor were often used. For example, an ASIC controller chip was often used to control the operation of the image sensor. As a further example, passive elements were combined to filter input signals to the image sensor.

The other associated electronic components were mounted to the printed circuit mother board separate from the image sensor package. However, this required area on the printed circuit mother board to be allocated for the other associated electronic components. Further, mounting the other associated electronic components at the printed circuit mother board level of fabrication was relatively labor-intensive, complex, and thus expensive.

As the art moved to smaller, lighter weight, and less expensive devices, the other associated electronic components were packaged along with the image sensor in an optical module, sometimes also called an image sensor package. The optical module was then mounted to the printed circuit mother board.

To form the optical module, the image sensor, along with the other associated electronic components, were mounted to a common substrate. Thus, although the optical module required less area to be allocated on the printed circuit mother board than mounting the other associated electronic components separately to the printed circuit mother board, area on the common substrate of the optical module was nevertheless allocated for the other associated electronic components. This, in turn, prevented miniaturization of the optical module.

SUMMARY OF THE INVENTION

Ad In accordance with one embodiment of the present invention, an optical module includes a window having an interior, e.g., first, surface. The interior surface includes a central region and a peripheral region. A first electronic component is coupled to the peripheral region. The optical module further includes a substrate and an image sensor coupled to the substrate. The window is coupled to the substrate such that the image sensor is aligned with the central region of the window.

In one embodiment, the peripheral region of the window is used to support the electronic component, which is associated with the image sensor. Since electromagnetic radiation passing through the peripheral region of the window is not used by the image sensor, the peripheral region can be obstructed by the electronic component without causing any detrimental performance of the image sensor.

Further, by using the peripheral region of the window to support the electronic component, the requirement to allocate area on the substrate for the electronic component is eliminated. Accordingly, the optical module can be formed to have a minimum size and is well suited for use with smaller, lighter weight, and less expensive devices, e.g., cameras and cellular telephones.

The present invention is best understood by reference to the following detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view of an optical module in accordance with one embodiment of the present invention.

FIG. **2** is a cross-sectional view of an optical module in accordance with another embodiment of the present invention.

FIG. **3** is a bottom plan view of a window assembly in accordance with one embodiment of the present invention.

FIG. **4** is a cross-sectional view of a window assembly during fabrication in accordance with one embodiment of the present invention.

FIGS. **5** and **6** are cross-sectional views of the window assembly of FIG. **4** at further stages of fabrication in accordance with embodiments of the present invention.

FIG. **7** is a cross-sectional view of the optical module of FIG. **1** during fabrication in accordance with one embodiment of the present invention.

Common reference numerals are used throughout the drawings and detailed description to indicate like elements.

DETAILED DESCRIPTION

In accordance with one embodiment of the present invention, a peripheral region PR of a window **130** (FIG. **1**) of an optical module **100** is used to support electronic components **132**, **154** associated with an image sensor **108**. Since electromagnetic radiation passing through peripheral region PR of window **130** is not used by image sensor **108**, peripheral region PR can be obstructed by electronic components **132**, **154** without causing any detrimental performance of image sensor **108**.

By using peripheral region PR of window **130** to support electronic components **132**, **15**,**4**, the requirement to allocate area on a substrate **102** for electronic components **132**, **154** is eliminated. Accordingly, optical module **100** can be formed to have a minimum size and is well suited for use with smaller, lighter weight, and less expensive devices, e.g., cameras and cellular telephones.

More particularly, FIG. **1** is a cross-sectional view of an optical module **100** in accordance with one embodiment of the present invention. Optical module **100** is used in a wide variety of applications, e.g., cameras and cellular telephones.

Optical module **100** includes a substrate **102**, e.g., formed of ceramic or laminate, although other substrate materials are used in other embodiments. Substrate **102** is a rectangular cup shape enclosure and includes a base **104** and a sidewall **106**. Sidewall **106** is formed around a periphery of base **104** and extended upwards, e.g., in a first direction, from base **104**. In this embodiment, base **104** and sidewall **106** are separate pieces connected together, e.g., with adhesive (not shown).

Base **104** includes an interior, e.g., first, surface **104I** and an exterior, e.g., second, surface **104E**. Mounted, sometimes called die attached, to interior surface **104I** is an image sensor **108**, sometimes called an electronic component. More particularly, a lower, e.g., first, surface **108L** of image sensor **108** is mounted to interior surface **104I** with an adhesive **110**, sometimes called a die attach adhesive.

Image sensor **108** further includes an upper, e.g., second, surface **108U**. An active area **112** and bond pads **114** of image sensor **108** are on upper surface **108U**. Although bond pads **114** are illustrated as being on both sides of image sensor **108**, in alternative embodiments, bond pads **114** are formed only along a single side of image sensor **108**. In this embodiment, interior surface **104I**, lower surface **108L**, and upper surface **108U** are parallel to one another.

Generally, active area **112** of image sensor **108** is responsive to electromagnetic radiation, as is well known to those of skill in the art. For example, active area **112** is responsive to infrared radiation, ultraviolet radiation, and/or visible light. Illustratively, image sensor **108** is a CMOS image sensor device, a charge coupled device (CCD), a pyroelectric device, or an erasable programmable read-only memory device (EPROM) although other image sensors are used in other embodiments.

A Formed on interior surface **104I** of substrate **102** are a plurality of electrically conductive interior traces **116**. Interior traces **116** are electrically connected to bond pads **114** by bond wires **118**. In one embodiment, bond wires **118** are enclosed within an encapsulant (not shown), which does not cover and leaves exposed active area **112**.

Formed on exterior surface **104E** of substrate **102** are a plurality of electrically conductive exterior traces **120**. Extending through base **104** from exterior surface **104E** to interior surface **104I** are a plurality of electrically conductive base vias **122**. Exterior traces **120** are electrically connected to interior traces **116** by base vias **122**. Base vias **122** which otherwise would not be visible in the view of FIG. **1** are indicated in dashed lines for purposes of illustration.

Formed on exterior traces **120** are electrically conductive pads **124**. Formed on pads **124** are electrically conductive interconnection balls **126**, e.g., solder. Interconnection balls **126** are used to connect optical module **100** to a larger substrate such as a printed circuit mother board.

In one embodiment, interior traces **116** and/or exterior traces **120** are covered with a dielectric protective layer, e.g., solder mask, as those of skill in the art will understand.

As set forth above, electrically conductive pathways between bond pads **114** and interconnection balls **126** are formed by bond wires **118**, interior traces **116**, base vias **122**, exterior traces **120**, and pads **124**.

Although a particular electrically conductive pathway between bond pads **114** and interconnection balls **126** is described above, other electrically conductive pathways can be formed. For example, contact metallizations can be formed between the various electrical conductors, e.g., between bond pads **114** and bond wires **118**, between bond wires **118** and interior traces **116**, between exterior traces **120** and pads **124**, and/or between pads **124** and interconnection balls **126**. Alternatively, pads **124** are not formed and interconnection balls **126** are formed directly on exterior traces **120**.

As yet another alternative, interconnection balls **126** are distributed in an array format to form a ball grid array (BGA) type package. Alternatively, interconnection balls **126** (or interconnection balls **126** and pads **124**) are not formed, e.g., to form a metal land grid array (LGA) type package. In yet another alternative, a leadless chip carrier (LCC) type package is formed. BGA, LGA and LCC type packages are well known to those of skill in the art. Other electrically conductive pathway modifications will be obvious to those of skill in the art.

Sidewall **106** of substrate **102** includes an interior surface **106I** and an exterior surface **106E**. In this embodiment, interior surface **106I** is parallel to exterior surface **106E**. Further, interior surface **106I** and exterior surface **106E** are perpendicular to interior surface **104I** and exterior surface **104E**, which are parallel to one another. Although various structures may be described as being parallel or perpendicular, it is understood that the structures may not be exactly parallel or perpendicular but only substantially parallel or perpendicular to within accepted manufacturing tolerances.

Extending between exterior surface **106E** and interior surface **106I** of sidewall **106** is a base mounting surface **106M** of sidewall **106** of substrate **102**. Base mounting surface **106M** of sidewall **106** is mounted to the periphery of interior surface **104I** of base **104**, e.g., with adhesive (not shown).

Opposite of base mounting surface **106M** and also extending between exterior surface **106E** and interior surface **106I** of sidewall **106** is a window mounting and connection surface **128** of sidewall **106** of substrate **102**. Window mounting and connection surface **128** is parallel to base mounting surface **106M**, interior surface **104I** and exterior surface **104E** of base **104** of substrate **102**. Window mounting and connection surface **128** is annular when viewed from above, e.g., is a rectangular annulus.

Mounted to substrate **102** is a window **130**. In this embodiment, window **130** is planar, i.e., is a flat piece. Window **130** includes an interior, e.g., first, surface **130I** and an exterior, e.g., second, surface **130E**. A side **130S** of window **130** extends between interior surface **130I** and exterior surface **130E**.

Exterior surface **130E** is exposed to the ambient environment. Although window **130** as a flat piece is set forth above and illustrated in FIG. **1**, in an alternative embodiment, window **130** has a different shape, e.g., is curved, cap shaped or otherwise has a non-planar shape.

Window **130** includes a peripheral region PR and a central region CR. Peripheral region PR is adjacent side **130S** of window **130** and extends around central region CR. Central region CR is aligned with and directly above active area **112** of image sensor **108**.

Window **130** is transparent to the electromagnetic radiation to which active area **112** of image sensor **108** is responsive. For example, window **130** is a glass window such as a borosilicate glass window although window **130** is formed of other materials such as plastic in other embodiments.

During use, electromagnetic radiation is directed at optical module **100** including image sensor **108**. This electromagnetic radiation passes through central region CR of window **130**. Central region CR of window **130** is unobstructed thus preventing distortion of the electromagnetic radiation passing through central region CR. After passing through central region CR of window **130**, the electromagnetic radiation strikes active area **112**, which responds to the electromagnetic radiation as is well known to those of skill in the art.

However, in an alternative embodiment, active area **112** of image sensor **108** transmits electromagnetic radiation. For example, image sensor **108** is a light emitting diode (LED) micro-display. In accordance with this embodiment, electromagnetic radiation transmitted by active area **112** passes through central region CR of window **130** and emanates from optical module **100**.

For simplicity, in the above and following discussions, active area **112** as a receiver of electromagnetic radiation is set forth. However, in light of this disclosure, those of skill in the art will recognize that generally active area **112** is a receiver of electromagnetic radiation, a transmitter of electromagnetic radiation, or a transceiver, i.e., a transmitter and a receiver, of electromagnetic radiation.

Peripheral region PR of window **130** is not aligned, sometimes called offset, from active area **112** of image sensor **108**. During use, electromagnetic radiation striking active area **112** has passed only through central region CR and not through peripheral region PR of window **130**. Since electromagnetic radiation passing through peripheral region PR of window **130** is not used by image sensor **108**, peripheral region PR of window **130** can be obstructed without causing any detrimental performance of image sensor **108**.

Peripheral region PR of window **130** is used to support electronic components associated with image sensor **108**. More particularly, these electronic components are mounted to peripheral region PR of interior surface **130I** of window **130**. Illustratively, (1) passive components such as inductors, resistors, capacitors; (2) active discrete components such as diodes; and/or (3) active components such as integrated circuits, are mounted to peripheral region PR of interior surface **130I** of window **130**. These electronic components are electrically connected to bond pads **114** of image sensor **108** and/or to interconnection balls **126** as discussed further below.

By using peripheral region PR of window **130** to support electronic components associated with image sensor **108**, the requirement to allocate area on substrate **102** for the electronic components is eliminated. Accordingly, optical module **100** can be formed to have a minimum size and is well suited for use with smaller, lighter weight, and less expensive devices, e.g., cameras and cellular telephones.

In accordance with this embodiment, optical module **100** includes an active component **132**, e.g., an integrated circuit such as a controller chip for image sensor **108**. Active component **132** is mounted to peripheral region PR of interior surface **130I** of window **130** in a wirebond configuration. More particularly, a rear surface **132R** of active component **132** is mounted to peripheral region PR of interior surface **130I** of window **130** by an adhesive **134**.

Formed on peripheral region PR of interior surface **130I** of window **130** are electrically conductive component traces **136**. Formed on component traces **136** are electrically conductive component pads **138**, sometimes called contact metallizations. Electrically conductive bond pads **140**, sometimes called terminals, on a front surface **132F** of active component **132** are electrically connected to component pads **138** and thus component traces **136** by electrically conductive bond wires **142**. Optionally, an encapsulant **143**, sometimes called a glob top encapsulant, is formed to enclose and protect active component **132**, bond wires **142**, component pads **138** and inner ends **136I** of component traces **136**.

Also formed on component traces **136** are electrically conductive window pads **144**, sometimes called contact metallizations. Illustratively, component pads **138** are formed on inner ends **136I** of component traces **136** and window pads **144** are formed on outer ends **136O** of component traces **136**, i.e., component pads **138** and window pads **144** are formed on opposite ends of component traces **136**.

Formed on window mounting and connection surface **128** are electrically conductive substrate pads **146**. Substrate pads **146** are electrically connected to window pads **144** by electrically conductive bumps **148**, e.g., solder, gold, or electrically conductive adhesive.

Substrate pads **146** are electrically connected to electrically conductive sidewall vias **150**. Sidewall vias **150** extend through sidewall **106** from window mounting and connection surface **128** to base mounting surface **106M** of sidewall **106**.

Also formed on interior surface **104I** of base **104** of substrate **102** are electrically conductive connector interior traces **152**. Connector interior traces **152** are formed adjacent image sensor **108**. Bond pads **114** of image sensor **108** are electrically connected to connector interior traces **152** by bond wires **118**.

Connector interior traces **152** extend along interior surface **104I** of base **104** from image sensor **108** to sidewall **106**. Connector interior traces **152** further extend between base mounting surface **106M** of sidewall **106** and interior surface **104I** of base **104** and to sidewall vias **150**. Connector interior traces **152** are electrically connected to sidewall vias **150**, e.g., by electrically conductive adhesive, solder, direct contact and/or other electrically conductive structures. In one embodiment, connector interior traces **152** and the corresponding sidewall vias **150** are integral, i.e., are parts of a single electrical conductor and are not separated electrical conductors connected together.

As set forth above, electrically conductive pathways between bond pads **114** of image sensor **108** and bond pads **140** of active component **132** are formed by bond wires **118**, connector interior traces **152**, sidewall vias **150**, substrate pads **146**, bumps **148**, window pads **144**, component traces **136**, component pads **138** and bond wires **142**.

Although a particular electrically conductive pathway between bond pads **114** of image sensor **108** and bond pads **140** of active component **132** is described above, other electrically conductive pathways can be formed. For example, contact metallizations can be formed between the various electrical conductors.

Alternatively, component pads **138** are not formed and bond wires **142** are directly connected to component traces **136**. As another alternative, window pads **144** and/or substrate pads **146** are not formed and component traces **136** are directly connected to sidewall vias **150** by bumps **148**.

Optical module **100** further includes a passive component **154** such as an inductor, a resistor, or a capacitor. Passive component **154** is a discrete surface mounted passive electronic component.

More particularly, passive component **154** includes terminals **156**. Terminals **156** are mounted to component pads **138** and thus component traces **136** by joints **158**, e.g., solder joints. Component traces **136** are electrically connected to sidewall vias **150** as described above.

In accordance with this embodiment, sidewall vias **150** are electrically connected to base vias **122**, e.g., by electrically conductive adhesive, solder, direct contact and/or other electrically conductive structures. As set forth above, base vias **122** extend through base **104** from interior surface **104I** to exterior surface **104E**. Base vias **122** are electrically connected to interconnection balls **126** as discussed above.

Thus, electrically conductive pathways between terminals **156** and interconnection balls **126** are formed by joints **158**, component pads **138**, component traces **136**, window pads **144**, bumps **148**, substrate pads **146**, sidewall vias **150**, base vias **122**, exterior traces **120**, and pads **124**.

Although a particular electrically conductive pathway between terminals **156** and interconnection balls **126** is described above, other electrically conductive pathways can be formed. For example, contact metallizations can be formed between the various electrical conductors.

Alternatively, component pads **138** are not formed and joints **158** are directly connected to component traces **136**. As another alternative, window pads **144** and/or substrate pads **146** are not formed and component traces **136** are directly connected to sidewall vias **150** by bumps **148**.

In an alternative embodiment, substrate **102** is integral, i.e., base **104** and sidewall **106** are parts of a single piece and are not separate pieces connected together. In accordance with this embodiment, sidewall vias **150** and the corresponding base vias **122** are integral, i.e., are parts of a single via and are not separate vias connected together.

Window **130** is mounted to window mounting and connection surface **128** of substrate **102** by bumps **148** in combination with a window adhesive **160**. Window adhesive **160** bonds a window mounting region MR of interior surface **130I** of window **130** adjacent side **130S** to window mounting and connection surface **128** of substrate **102**. To the extent that window **130** has a different thermal coefficient expansion than substrate **102**, window adhesive **160** minimizes failure of bumps **148** from thermal stresses between window **130** and substrate **102**.

Further, window adhesive **160** forms a seal between window **130** and substrate **102**, which protects image sensor **108** and the electronic components mounted to interior surface **130I** of window **130**, e.g., active component **132** and passive component **154**, from environmental degradation, e.g., from dust and moisture.

More particularly, substrate **102**, window **130** and window adhesive **160** form an enclosure around image sensor **108**, active component **132** and passive component **154** and protect image sensor **108**, active component **132** and passive component **154** from the ambient environment.

FIG. **2** is a cross-sectional view of an optical module **200** in accordance with another embodiment of the present invention. Optical module **200** of FIG. **2** is similar to optical module **100** of FIG. **1** and only the significant differences are discussed below.

Referring now to FIG. **2**, substrate **102A** is integral, i.e., base **104** and sidewall **106** are parts of a single piece and are not separate parts connected together. Further, sidewall vias **150** and the corresponding base vias **122** are integral, i.e., sidewall vias **150** and the corresponding base vias **122** are parts of single vias **202** and are not separate vias connected together.

Further, bond wires **118** electrically connect bond pads **114** of image sensor **108** to connector traces **204**. Connector traces **204** extend along interior surface **104I** of base **104** from image sensor **108** to sidewall **106**. Connector traces **204** further extend along interior surface **106I** of sidewall **106** from base **104** to window mounting and connection surface **128**. Connector traces **204** further extend from interior surface **106I** of sidewall **106** along window mounting and connection surface **128**. Substrate pads **146** are formed on connector traces **204**.

Optical module **200** further includes an active component **132A**. Active component **132A** is mounted to peripheral region PR of interior surface **130I** of window **130** in a flip chip configuration. More particularly, bond pads **140**, sometimes called terminals, on front surface **132F** of active component **132A** are electrically connected to component pads **138** and thus component traces **136** by electrically conductive bumps **206**, sometimes called flip chip bumps.

Optionally, an underfill **208** fills the region between front surface **132F** of active component **132A** and interior surface **130I** of window **130**. Underfill **208** encloses and protects bumps **206**, component pads **138** and inner ends **136I** of component traces **136**.

Optical module **200** further includes an active discrete component **210**, e.g., a diode. Active discrete component **210** is mounted to peripheral region PR of interior surface **130I** of window **130**. More particularly, a rear surface **210R** of active discrete component **210** is mounted to a component pad **138** and thus to a component trace **136** by an electrically conductive adhesive **212**, e.g., solder or electrically conductive epoxy.

An electrically conductive bond pad **214**, sometimes called a terminal, on a front surface **210F** of active discrete component **210** is electrically connected to a component pad **138** and thus to a component trace **136** by an electrically conductive bond wire **216**.

FIG. **3** is a bottom plan view of a window assembly **300** in accordance with one embodiment of the present invention. As shown in FIG. **3**, window assembly **300** includes a window **130A** having an interior surface **130I**. Interior surface **130I** includes central region CR and peripheral region PR. In this embodiment, central region CR is located at or near a center **302** of interior surface **130I** of window **130**. However, as described above, central region CR is aligned with active area **112** of image sensor **108** (FIG. **1**). Accordingly, in other embodiments, central region CR is offset from center **302** depending upon the particular location of image sensor **108**.

The portion of interior surface **130I** of window **130** other than central region CR forms peripheral region PR. In this embodiment, peripheral region PR surround central region CR and extends between side **130S** of window **130A** and central region CR.

Peripheral region PR includes an electronic component mounting region ER and a window mounting region MR. As shown in FIG. **3**, window mounting region MR is a rectangular annulus formed directly adjacent side **130S** around the entire periphery of interior surface **130I** of window **130A**. As discussed above, window mounting region MR is bonded to window mounting and connection surface **128** of substrate **102** (FIG. **1**).

The portion of interior surface **130I** of window **130A** other than central region CR and window mounting region MR is electronic component mounting region ER. Generally, electronic components are mounted to electronic component mounting region ER.

In this embodiment, active component **132**, active component **132A**, active discrete component **210**, and passive component **154** are mounted generally to interior surface **130I**, and, more particularly, to peripheral region PR of interior surface **130I**, and, specifically, to electronic component mounting region ER of peripheral region PR of interior surface **130I** of window **130A**. Active component **132**, active component **132A**, active discrete component **210**, and passive component **154** are mounted as discussed above in reference to FIGS. **1** and **2**.

As shown in FIG. **3**, component traces **136** extend from electronic component mounting region ER to window mounting region MR. More particularly, inner ends **136I** of component traces **136** and, if formed, component pads **138** are formed within and are on electronic component mounting region ER. Outer ends **136O** of component traces **136** and, if formed, window pads **144** are formed within and are on window mounting region MR of interior surface **130I** of window **130A**. Outer ends **136O** of component traces **136** and, if formed, window pads **144** are sometimes called input/output (I/O) pads.

In one embodiment, electronic components mounted to electronic component mounting region ER are electrically connected to one another by electrically conductive component interconnection traces **304** formed on interior surface **130I** of window **130A**. For example, electronic components mounted to electronic component mounting region ER are electrically connected to one another to form circuit elements such as filters.

To illustrate, referring still to FIG. **3**, a resistor **306** and an inductor **308** are formed on and/or mounted to interior surface **130I** of window **130**. Inductor **308**, resistor **306**, and passive component **154**, e.g., an inductor, resistor, or capacitor, are electrically connected to one another by component interconnection traces **304** to form a circuit element such as a filter.

FIG. **4** is a cross-sectional view of a window assembly **300A** during fabrication in accordance with one embodiment of the present invention. As shown in FIG. **4**, component traces **136** are formed on interior surface **130I** of window **130**.

In one embodiment, component traces **136** are thin film metallizations, e.g., having a thickness of **10**m although component traces **136** have other thicknesses in other embodiments. For example, component traces **136** are formed by sputtering or otherwise depositing an electrically conductive material such as a metal containing material. A mask, e.g., photoresist, is formed on the electrically conductive material. The electrically conductive material is etched, and the mask is removed. Generally, an electrically conductive material is formed on interior surface **130I** and then selectively patterned to form component traces **136**.

In another embodiment, component traces **136** are thick film metallizations. For example, component traces **136** are formed by screen printing an electrically conductive paste, and then heating the screened paste. Generally, an electrically conductive material is selectively formed to form component traces **136**.

In one embodiment, referring now to FIGS. **3** and **4** together, inductor **308**, resistor **306** and/or component interconnection traces **304** are formed simultaneously with component traces **136**. However, in alternative embodiments, as described further below, inductor **308** and/or resistor **306** are separate electronic components, which are mounted to component traces **136**.

FIG. **5** is a cross-sectional view of window assembly **300A** of FIG. **4** at a further stage of fabrication in accordance with one embodiment of the present invention. As shown in FIG. **5**, component pads **138** and window pads **144** are formed on component traces **136**. More particularly, component pads **138** are formed on inner ends **136I** of component traces **136**. Window pads **144** are formed on outer ends **136O** of component traces **136**. Illustratively, component pads **138** and window pads **144** are formed by plating or otherwise selectively depositing an electrically conductive material on inner ends **136I** and outer ends **136O** of component traces **136**, respectively. However, in alternative embodiments, component pads **138** and/or window pads **144** are not formed.

FIG. **6** is a cross-sectional view of window assembly **300A** of FIG. **5** at a further stage of fabrication in accordance with one embodiment of the present invention. As shown in FIG. **6**, active component **132** and passive component **154** are mounted to electronic component mounting region ER of peripheral region PR of interior surface **130I** of window **130**. Illustratively, joints **158**, e.g., solder, are formed between terminals **156** of passive component **154** and component pads **138** to mount passive component **154**.

To mount active component **132**, rear surface **132R** of active component **132** is attached to interior surface **130I** by adhesive **134**. Bond pads **140** of active component **132** are electrically connected to component pads **138**/component traces **136** by bond wires **142** using a wirebonding tool. Optionally, encapsulant **143** is applied to enclose bond pads **140**, bond wires **142**, component pads **138**, and inner ends **136I** of component traces **136**.

Although mounting of active component **132** and passive component **154** is illustrated in FIG. **6** and discussed above, in light of this disclosure, those of skill in the art will understand that a wide variety of electronic components can be mounted to electronic component mounting region ER of peripheral region PR of interior surface **130I** of window **130** in accordance with alternative embodiments of the present invention. For example, referring to FIGS. **3** and **6** together, active component **132A**, active discrete component **210**, resistor **306**, and/or inductor **308** are mounted to electronic component mounting region ER of peripheral region PR of interior surface **130I** of window **130**.

FIG. **7** is a cross-sectional view of optical module **100** of FIG. **1** during fabrication in accordance with one embodiment of the present invention. Referring now to FIG. **7**, window assembly **300A** is aligned with substrate **102**. More particularly, window mounting region MR of interior surface **130I** of window **130** is aligned with window mounting and connection surface **128** of substrate **102**. Window mounting region MR is aligned with window mounting and connection surface **128** such that outer ends **136O** of component traces **136** and, if formed, component pads **144** are aligned with corresponding sidewall vias **150**, and, if formed, substrate pads **146**.

Referring now to FIGS. **1** and **7** together, bumps **148** are formed between outer ends **136O**/component pads **144** and sidewall vias **150**/substrate pads **146**. Further, window adhesive **160** is formed between window mounting region MR and window mounting and connection surface **128**. In one embodiment, bumps **148** and window adhesive **160** are formed simultaneously. However, in alternative embodiments, bumps **148** are formed before window adhesive **160** or vice versa.

This disclosure provides exemplary embodiments of the present invention. The scope of the present invention is not limited by these exemplary embodiments. Numerous variations, whether explicitly provided for by the specification or implied by the specification, such as variations in structure, dimension, type of material and manufacturing process may be implemented by one of skill in the art in view of this disclosure.

What is claimed is:

1. A structure comprising:

a window comprising a first surface, said first surface comprising a central region and a peripheral region, wherein said central region is unobstructed; and

a first electronic component coupled to said peripheral region.

2. The structure of claim **1** further comprising a component trace coupled to said first surface of said window, a terminal of said first electronic component being coupled to said component trace.

3. The structure of the claim **2** wherein said terminal is coupled to an inner end of said component trace.

4. The structure of claim **3** wherein an outer end of said component trace comprises an input/output (I/O) pad.

5. The structure of claim **4** further comprising a window pad coupled to said outer end of said component trace, said window pad forming said input/output pad.

6. The structure of claim **4** wherein said peripheral region comprises a window mounting region, said outer end of said component trace being coupled to said window mounting region.

7. The structure of claim **6** wherein said peripheral region further comprises an electronic component mounting region, said inner end of said component trace being coupled to said electronic component mounting region.

8. The structure of claim **7** wherein said component trace extends from said electronic component mounting region to said window mounting region.

9. The structure of claim **2** wherein said terminal is coupled to said inner end of said component trace by a bond wire.

10. The structure of claim **2** wherein said terminal is coupled to said inner end of said component trace by a flip chip bump.

11. The structure of claim **2** wherein said terminal is coupled to said inner end of said component trace by a solder joint.

12. The structure of claim **1** wherein said electronic component is selected from the group consisting of a passive component, an active discrete component, and an active component.

13. A structure comprising:

a window comprising a first surface, said first surface comprising a central region and a peripheral region;

a first electronic component coupled to said peripheral region;

a substrate, said window being coupled to said substrate; and

an image sensor coupled to said substrate, said image sensor being aligned with said central region.

14. The structure of claim **13** wherein said central region is unobstructed.

15. The structure of claim **13** wherein said image sensor comprises an active area, said active area being a receiver, a transmitter, or a transceiver of electromagnetic radiation.

16. The structure of claim **15** wherein said window is transparent to said electromagnetic radiation.

17. The structure of claim **13** wherein said electronic component comprises a terminal coupled to a bond pad of said image sensor.

18. A method comprising:

forming a component trace on a peripheral region of a first surface of a window;

mounting an electronic component to said peripheral region, wherein a terminal of said electronic component is coupled to said component trace.

19. The method of claim **18** wherein said peripheral region comprises an electronic component mounting region and a window mounting region, said electronic component being mounted to said electronic component mounting region, an outer end of said component trace forming an input/output pad on said window mounting region.

20. The method of claim **19** further comprising:

coupling said window mounting region of said window to a substrate; and

coupling said outer end of said component trace to a substrate pad on said substrate.

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